PHYSIOLOGIC STUDIES ON THE VASCULAR SENSIBILITY

by

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CONTENTS

I INTRODUCTION

The presence of vascular sensibility has long been known. A great number of reports have been published on the sensory innervation of the blood vessels. Most of those works were carried on to analyse the conducting pathway of the sensory fibers. ASAI (1927) and KOYA (1932), in animal experiments, reported that the blood vessels of abdominal cavity had a dual sensory supply via the afferents of the sympathetic and parasympathetic systems, and that those of extremities likewise had a dual supply via the sympathetic and somatic nerves, except for a triple supply in the axillary artery. The very opposite observations are those of ŌSAWA (1926), MOORE and SINGLETON (1933), who proved that the sensory fibers supplying the femoral and brachial arteries passed the peripheral branches of the spinal nerves, but not the sympathetic chain.

The purpose of the present investigation is to observe the noci-reflexes elicited by noci-stimuli of the blood vessels by means of a new experimental method, and thereby to clarify: 1) the systematic analysis and evaluation of the vascular sensibility in various parts of the body, 2) the pursuit of conducting pathway of the sensibility, inter alia, parasympathetic sensible pathway, and 3) considerations on the spinal segments in which sensory innervation to the blood vessels, especially to the main abdominal vessels, consist.

II ANIMAL EXPERIMENTS

METHODS

Experimental animals

Dogs were used in all experiments. Urethane and morphine were used as anesthetics, because with these drugs a steady narcosis was readily obtained and because deep anesthesia with other anesthetics suppressed a response upon stimulation.

Recording

As the indicator of the vascular sensibility, noci-reflexes, i. e., the changes of blood pressure and respiration, were recorded on a kymogram. The blood pressure was directly measured from the carotid artery with the mercury manometer. The respiration curves were recorded with the water manometer connected through rubber tubing with a rubber bulb placed on the chest wall.

Stimulation

A new method was devised by the author. The inner surface of the blood vessels was electrically stimulated by the coaxial electrodes which were set on the top of a heart catheter inserted into the blood vessels. By this method the author could examine genuine vascular sensibility, of the brachial artery, femoral artery, aorta, vena cava inferior and other vessels without performing thoracotomy or laparotomy.

The stimuli given to the blood vessels consisted of square wave unidirectional pulses with a duration of 5.0 msec, a frequency of 60 pulses per second, and intensities varying between 1 and 40 volts. The center pole of the stimulating electrodes served as an anode.

Insertion of the catheter electrodes

In most experiments of the present studies, the heart catheter was inserted into aimed positions under the fluoroscopy from the following five blood vessels:

brachial artery ⟶ axillary a., subclavian a., aortic arch.
femoral artery ⟶ external iliac a., common iliac a., abdominal aorta, thoracic aorta, aortic arch.
external jugular vein ⟶ pulmonary a.
femoral vein ⟶ v. cava inferior
common carotid artery ⟶ carotid sinus, external carotid a.

In a few cases, i. e., in popliteal a., celiac a., superior mesenteric a., and inferior mesenteric a., a slender vinyl-tube was used instead of the heart catheter, because these vessels were small calibre.

In the case of abdominal visceral arteries only, the electrodes were inserted under laparotomy. Thereafter, the abdominal cavity was immediately closed in order to avoid influences of any artefact.

RESULTS

(1) *Observaion on the peripheral arteries*

Upper extremity: Brachial artery, Axillary artery, Subclavian artery

Stimulation to these arteries was followed by a remarkable reflex reaction (Fig. 1). The result is presented en bloc in Table I.

Although it is considerably difficult to give an exact and objective judgment on the evaluation of vascular sensibility, these arteries presented the following order in their sensitivity: brachial a. > axillary a. > subclavian a.

Lower extremity: Popliteal artery, Femoral artery, External iliac artery, Common iliac artery

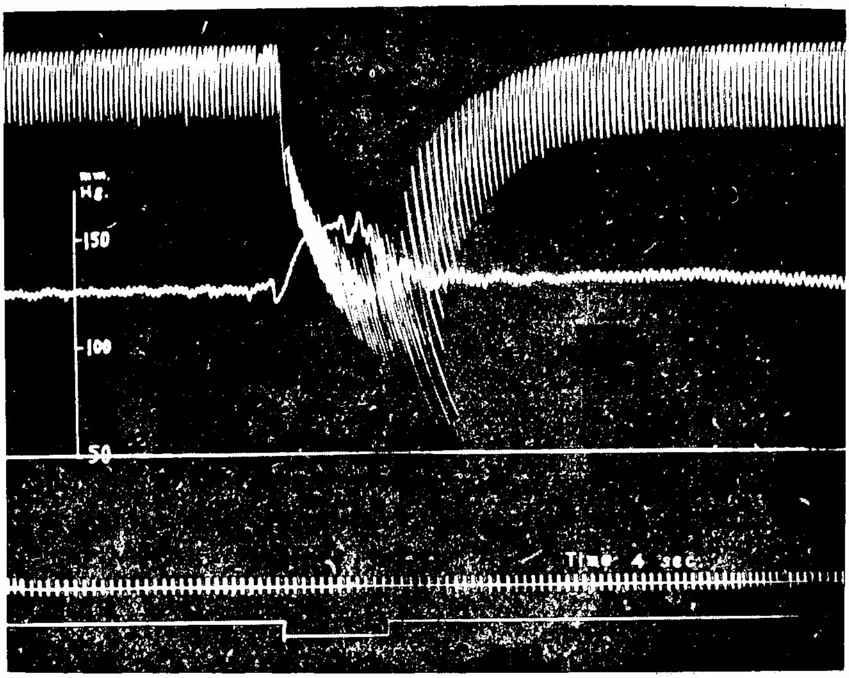

Fig. 1 Femoral artery. The marked increase of blood pressure, and the notable change of respiration accompanied by crying and struggling were recorded by stimulating the artery. The tracings from up to down: respiration, blood pressure, baseline, time and signal. In following all figures the tracings are the same as in this figure.

The similar responses were obtained in these arteries, too. The result is given in Table I. Comparing the sensibility of these arteries, the following order was recognized : popliteal a. > femoral a. > external iliac a. > common iliac a.

Experiment of nerve section

In one animal, the femoral artery was stimulated before and after the section of both femoral and sciatic nerves at the muscular lacuna and sciatic foramen respectively. When the stimulation was given before the section of these nerves, a very remarkable reflex reaction was observed. After the section of the nerves, this reaction diminished, but a slight change still remained. In another animal, the artery was stimulated before and after the homolateral lumbosacral sympathectomy (L2-S3). The resection of the sympathetic chains gave some influence on this reaction.

(2) *Observation on two abdominal large blood vessels*

Abdominal aorta

The vessel was stimulated at the level of the second lumbar vertebra. Almost the same reflex reactions were recognized by increasing intensity from 10 to 40 volts. Fig. 3-b. shows the pressor response following the stimulation of the aorta.

Inferior vena cava

The vein was stimulated at the same level as examined in the abdominal aorta. When 40 volts intensity was applied, the blood pressure and respiration showed

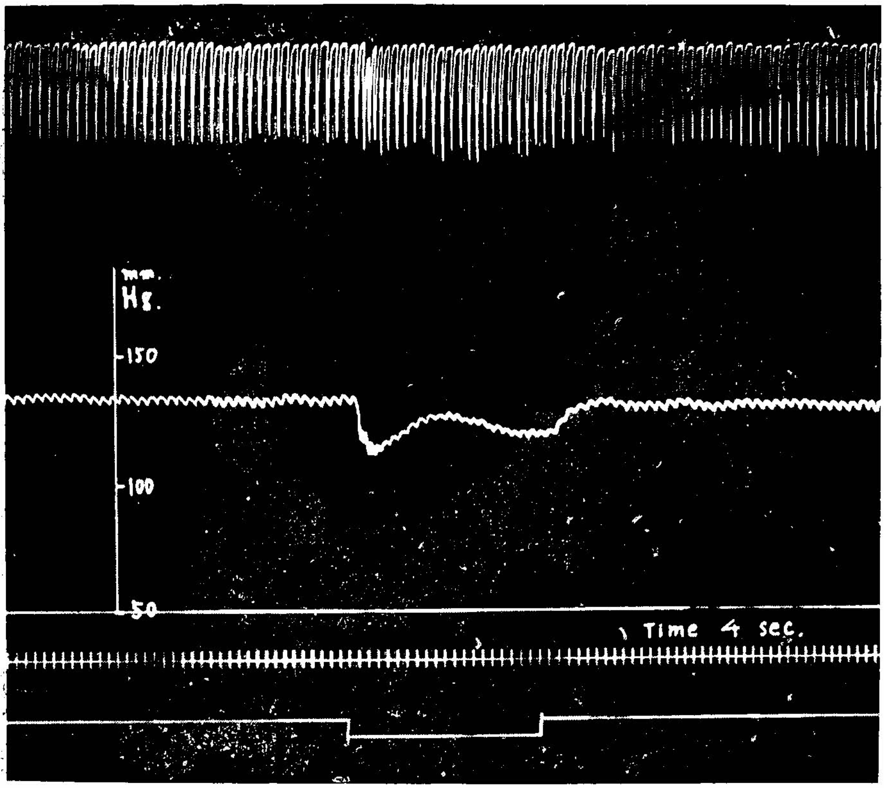

Fig. 2 Aortic arch. The distinct decrease of blood pressure and the temporary change of respiration, by stimulating the arch with catheter electrode.

essentially the same changes as in the experiment of the abdominal aorta. But the intensity below 30 volts, had no effect upon it.

The threshold intensities in the abdominal aorta and the vena cava were 5 volts and 30 volts respectively, the former being more sensitive than the latter.

(3) *Observation on thoracic large blood vessels*

Aortic arch

Fig. 2 shows a distinct decrease of blood pressure. When the same portion was stimulated 2 hours after the vagotomy on the left side, the depressor reflex was still observed. After the bilateral cervical vagotomy, the reflex was recognized no more.

Thoracic aorta

When the aorta was stimulated at the level of the ninth thoracic vertebra, reflex changes were relatively slight.

Pulmonary artery

Notable reduction of blood pressure occurred following the stimulation of the trunk of this artery (Fig. 3-a). Two hours after the left cervical vagotomy, the same intensity of stimulus still produced slight changes in both blood pressure and respiration. After additional right cervical vagotomy, these vasopressor and respiratory reactions completely disappeared. During this time, the femoral artery which

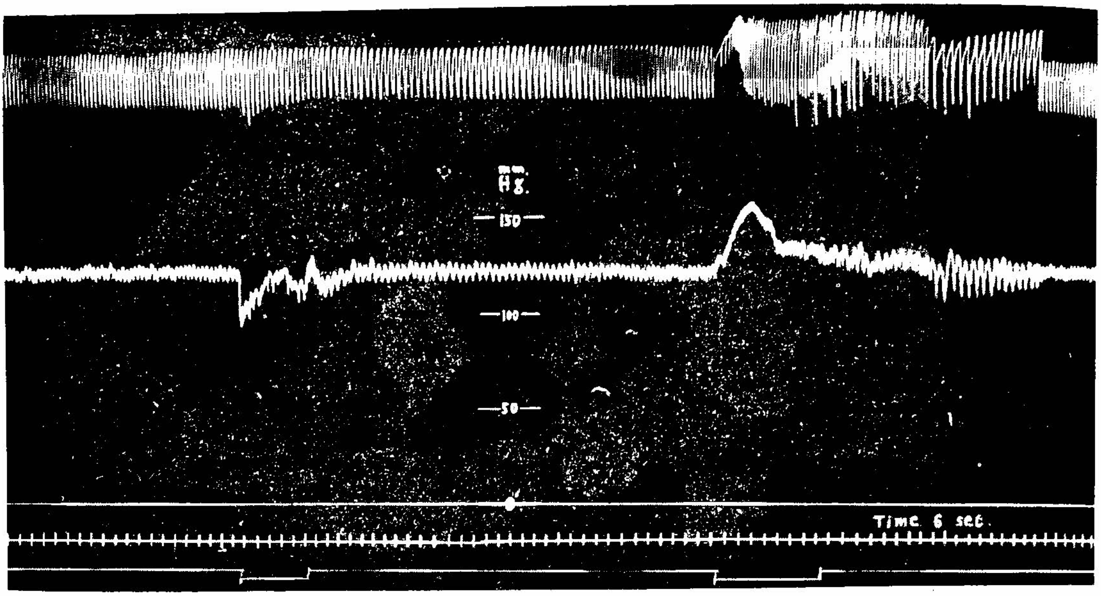

Fig. 3 a. Pulmonary artery. b. Abdominal aorta.
Compare a with b. Both the same intensity: 30 volts. The precipitous fall of blood pressure and the slight change of respiration were recorded by stimulating the pulmonary artery. On the contrary, the marked increase of blood pressure and the change of respiration were shown by stimulating the abdominal aorta.

was stimulated as control showed a marked reaction.

If the intra-pulmonary artery was stimulated, pressor response and respiratory change were obtained. By bilateral vagotomy, the former response disappeared but the latter change still remained. The conus arteriosus, likewise, showed a tendency to pressor response. The result following the vagotomy was the same as in the intra-pulmonary artery.

(4) *Observation on the cervical arteries*

Carotid sinus

The stimulation of the carotid sinus caused a reduction of blood pressure and a slight change of respiration (Fig. 4). The response disappeared after the section of the carotid sinus nerve.

Common carotid artery and external carotid artery

In these arteries, a very slight reflex reaction was recognized throughout the entire experiments of the present studies, except for a questionable response to the portal vein.

(5) *Observation on the abdominal visceral arteries*

Celiac artery

By stimulating this artery pressor and respiratory reflex reactions were observed (Fig. 5-a).

In order to decide the afferent pathways participating in the noci-reflexes,

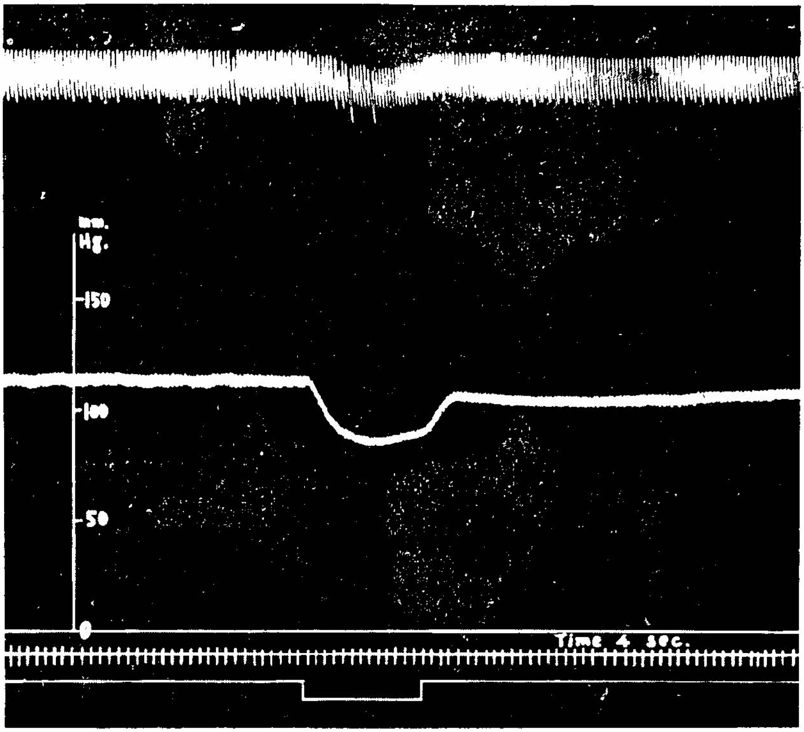

Fig. 4 Carotid sinus. Showing remarkable depressor responses recorded by stimulating the sinus with catheter electrode.

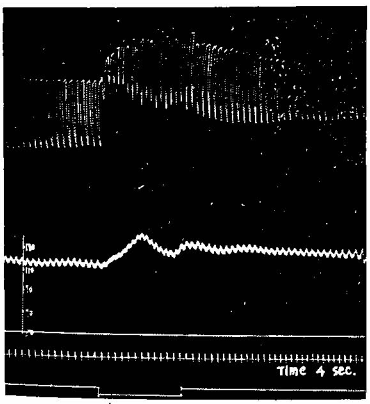

Fig. 5-a Celiac artery. Nerve intact, marked changes of blood pressure and respiration.

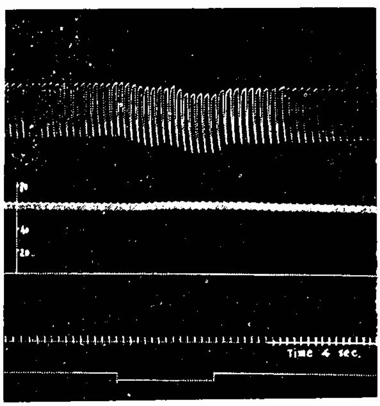

Fig. 5-b Celiac artery. After transection at C8, reactions diminished, but slight changes still remained.

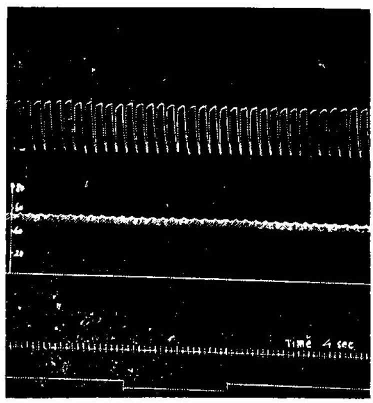

Fig. 5-c Celiac artery. Additional bilateral vagotomy performed, vasopressor and respiratory reactions completely disappeared.

transection of the spinal cord and cervical vagotomy were carried out. After transection of the spinal cord at C 8, some slight changes still remined (Fig. 5-b). Thereafter, additional bilateral vagotomy was performed. Hereupon, the vasopressor and respiratory reactions completely disappeared (Fig. 5-c). Contrary to the above experiment, the bilateral vagotomy was, at first, performed. The reaction diminished only slightly. Additional transection of the spinal cord at C 8 caused the reaction to disappear completely.

These experiments demonstrate that some of the afferent fibers concerned in the response to electrical stimulation of this artery ascend in the spinal cord via the abdominal sympathetic pathways, while others of them ascend in the vagus nerve, to reach the medulla oblongata.

In order to decide the upper and lower borders of the spinal segments communicated with the sympathetic afferent pathways, transection of the spinal cord and posterior rhizotomy were performed.

After vagal afferent paths were intercepted by preceding bilateral vagotomy (Fig. 6-a), the transection of the spinal cord was performed at L 1. Following this, the stimulation of the artery elicited distinct reflex changes (Fig. 6-b). Then, the cord was transected from Th13 to Th7 in turn (Fig. 6-c, d, e, f, g, h.). At Th7, the reflexes completely disappeared (Fig. 6-i). This indicates that the upper border is the 7th thoracic segment.

In another animal, posterior rhizotomy was performed at Th7 after bilateral vagotomy. The stimulation caused the reflex responses. Thereafter, the posterior

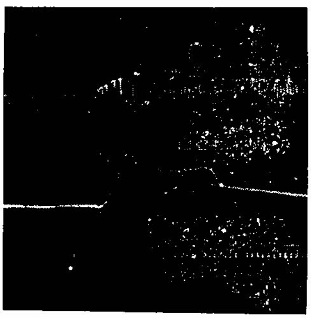
Fig. 6-a

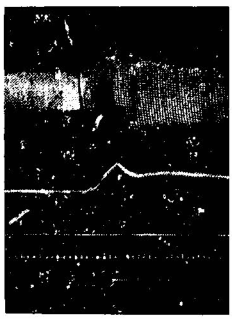
Fig. 6-b

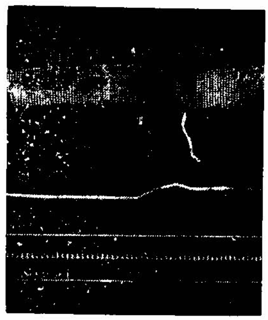
Fig. 6-c

a. Stimulated after bilateral vagotomy.
b. Stimulated after transection at L1.
c. Stimulated after transection at Th13.

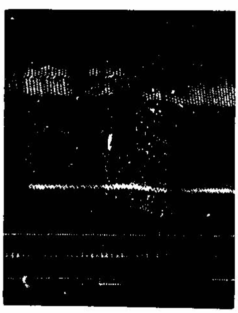
Fig. 6-d

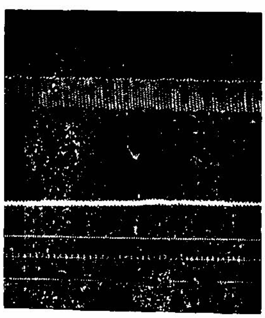
Fig. 6-e

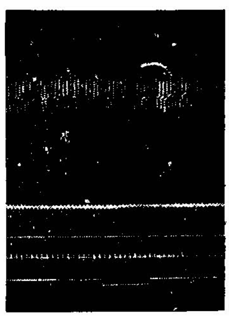
Fig. 6-f

d. Stimulated after transection at Th12.
e. Stimulated after transection at Th11.
f. Stimulated after transection at Th10.

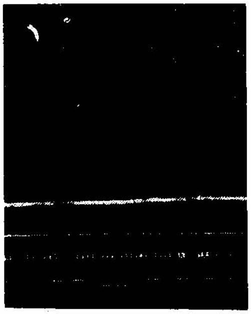

Fig. 6-g

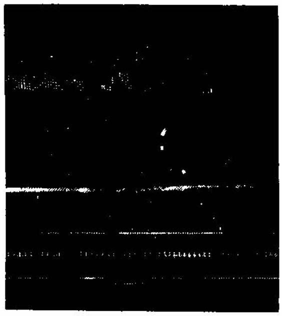

Fig. 6-h

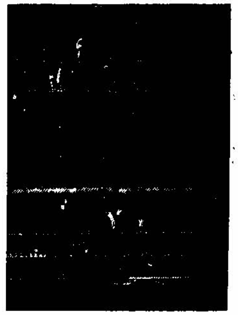

Fig. 6-i

g. Stimulated after transection at Th9.
h. Stimulated after transection at Th8.
i. Stimulated after transection at Th7.

rhizotomy was performed from Th8 to Th13 in turn. At Th13, the reflex completely disappeared. This proves that the lower border is the lst lumbar segment.

Superior mesenteric artery

For the purpose of studying the afferent pathways of the noci-reflex evoked from the superior mesenteric artery, the same procedure as demonstrated in the celiac artery was carried out. The result indicated that the superior mesenteric artery was innervated by both the sympathetic and vagal afferent nerves, and that the upper border of the spinal segments communicated with the sympathetic afferent pathways was Th9, and the lower one L2.

Inferior mesenteric artery

In this artery, the noci-reflexes disappeared after the transection of the spinal cord at C 8, without performing vagotomy. This fact showed that the vagal nerve did not play any rôle in conducting afferent impulses which arose from the inferior mesenteric artery. The upper border of the spinal segments concerning the reflex was L1 and the lower border was L5.

DISCUSSION

Criticism on the experimental methods

Various methods of stimulation have been devised so far by many workers for studying vascular sensibility. Among others, the method reported by Moore and Singleton is widely adopted by many investigators. They succeeded in arousing vascular pain by giving an intra-arterial injection of sodium iodide solution. But this chemical method can not be regarded as ideal for stimulating the blood vessel itself, because it is thought that the irritant flows to the periphery from the site of injection and stimulates the sensory nerve ending of the skin or other tissues supplied by the vessel.

Ch. Kimura, who studied the problem clinically showed that the pain caused by injecting sodium iodide solution was felt by leprous patients only where the cutaneous sensibility was normal and not in the anesthetic skin area. From this evidence he concluded that Moore and Singleton's sodium iodide method caused the pain of the skin.

The present author directly proved the irritant action of the chemicals upon the sensory nerve endings of the skin. In accordance with ARMSTRONG's cantharidin blister method, an isotonic sodium iodide solution was applied to the blister area so as to action the nerve endings directly. Immediately a very severe pain occurred and persisted a few minutes. Besides, as will be described later, the barium chloride solution which was injected into the artery caused a severe pain in the peripherally distant parts. Therefore, the chemical method was avoided in the present studies.

Electrical or mechanical stimulation methods have widely been employed. KOYA, ASAI and others stimulated the blood vessels with Faradic current at a point on adventitia. This method also lacks adequacy for stimulating the blood vessels, because not only tested vessels must be exposed to non-physiological state but also other nerve elements which have no direct relation with vascular afferent nerve fibers may be stimulated. In the adventitia of a blood vessel, existence of those nerve fibers must be taken into consideration. By mechanical method, the adequate intensity of stimuli cannot be given to the vessels.

In order to avoid the disadvantages of the above-mentioned methods and to stimulate the needed blood vessel and no other, a new method was devised by the present author. The method consists in stimulating the vessel from inside. For this purpose, a heart catheter, on the top of which the coaxial electrodes were set, was used. Almost all vessels were stimulated with this catheter electrodes inserted into them, without damaging the finest nerve fibers.

Quantitative evaluation of vascular sensibility

In order to decide the intensity of threshold stimuli a part of a blood vessel was stimulated repeatedly at intervals of 5 to 10 minutes with increasing intensites in one experiment, while in another experiment, the same intensity of stimulus was given to more than two vessels in order to compare the degrees of response.

From the threshold and the response, vascular sensitivity can be estimated. For example, the result of the brachial, axillary, subclavian artery or the popliteal, femoral, external iliac, common iliac artery, shows that the more peripheral the stimulated portion is, the lower the threshold of stimulus is, in other words, the higher the response to stimulus is.

Comparing the vascular sensibility of the extermities with that of the main blood vessels in the trunk, the latter was less sensitive than the former.

The result of the experiments on the abdominal aorta and vena cava inferior showed that the former was more sensitive than the latter. A similar relation was observed between the mesenterial artery and the portal vein. CHENG of our laboratory, who carried out a histological study on the afferent innervation of the large blood vessels, has recently reported that the nerve distribution in the large veins is far more scarce than in the large arteries. His histological finding coincides with the physiological result of the present experiments.

According to M. CLARA, the vascular sensibility has not been proved in the common carotid artery. But in the present experiment, the distinct noci-reflex was

Table. I Grade of Reflex Responses following Stimulation of Peripheral and Visceral Blood Vessels.

	Increase of blood pressure			Change of respiration			Crying		Struggling	
	marked	moderate	slight	marked	moderate	slight	marked	slight	marked	slight
Brachial a.	+			+			+		+	
Axillary a.	+			+				+		+
Subclavian a.		+			+					
Popliteal a.	+			+			+		+	
Femoral a.	+			+			+		+	
External iliac a.		+			+			+		+
Common iliac a.		+			+					
Comon carotid a.			+			+				
External carotid a.			+			+				
Abdominal aorta		+			+					
Thoracic aorta			+		+					
Inferior vena cava		+				+				
Portal vein			+(?)			+(?)				
Celiac a.		+			+					
Superior m. a.		+			+					
Inferior m. a.		+			+					
Carotid sinus, Aortic arch, Pulmonary a.	Depressor respons									

Intensities of stimuli:
20 volts, in arteries of upper and lower extremities
20-40 volts, in other blood vessels
(?) : sometimes questionable

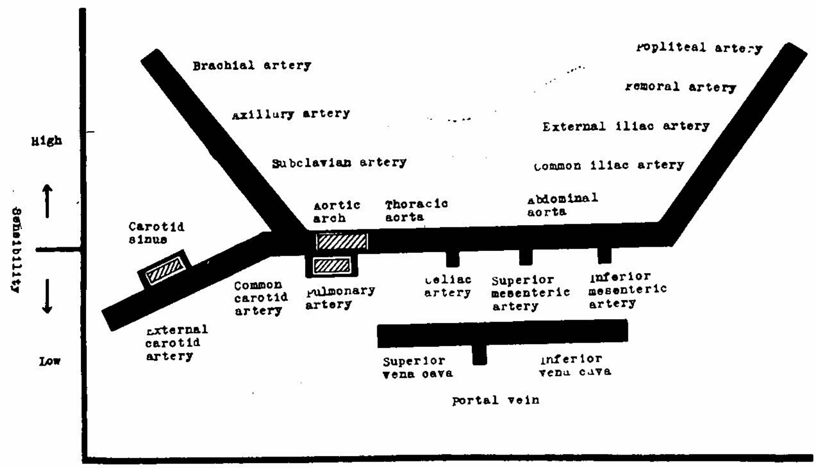

Fig. 7 Graphic curve showing grade of vascular sensibility in many blood vessels. Refer to the result in Table 1. Upward arrow shows high sensibility, and downward one shows inverse.

elicited by stimulating the artery, althouth the response was very slight.

The result is summarized in Table I and illustrated in Fig. 7.

Depressor reflex and noci-reflex

The reflexes arising from the blood vessels were classified into two main kinds, depressor reflex and noci-reflex. As well known, the depressor reflexes occur from the aortic arch, carotid sinus and the bifurcation of pulmonary arteries. In the present experiments, by means of author's method, these phenomena were clearly recorded, and it was also demonstrated that aortic and pulmonary reflexes disappeared after the vagus nerve was cut and that carotid reflex did not occur after section of the sinus nerve. The noci-reflex, including the increase of blood pressure, change of respiration, struggling and crying, was employed in the present study as an indicator of vascular sensibility. As shown in Table I, these reflex reactions were recorded from all blood vessels examined.

Thus, it may be given as a conclusion that the depressor receptors are localized on the specific sites, while the noci-receptors are distributed on almost all blood vessels, and that the afferent conducting pathway of the former, i. e., "baroceptive fiber", ascends to the cardiovascular center, accompanied with the vagus nerve, whereas the afferent fibers of the latter reach the upper center through the sympathetic nerve.

The depressor reflex coming from the pulmonary artery was described by Takino (1937) and is now giving an important problem in thoracic surgery. The author experimentally recognized the existence of this depressor reflex using the heart cather electrodes without thoracotomy. The depressor reflex which was present in pulmonary trunk was not proved in the intra-pulmonary artery. If the artery was stimulated by the catheter electrodes which were more deeply inserted from the pulmonary trunk, the noci-reflex developed. From the result of vagotomy, it is understood that

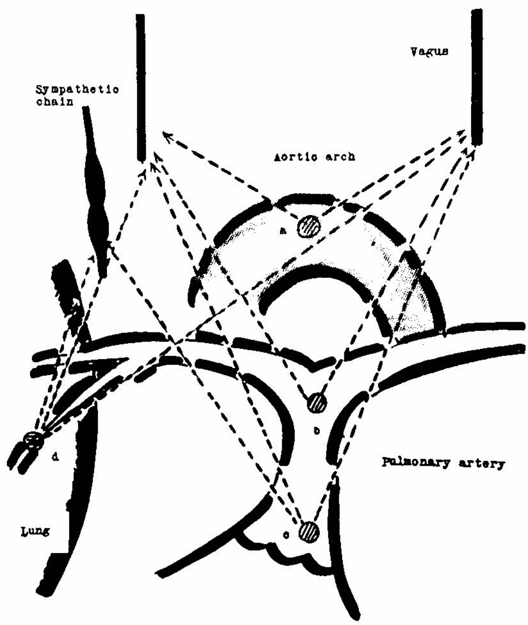

Fig. 8 Showing the afferent conducting pathways of depressor reflexes arising from the aortic arch (a) and the trunk of pulmonary artery (b), and the pathways of noci-reflexes occurring from the intra-pulmonary artery (d) and the conus arteriosus (c).

the afferent impulses arising from the trunk of pulmonary artery ascend through the vagus nerve, while the impulses from the intra-pulmonary artery are conveyed by dual pathways, viz, the vagus nerve and thoracic sympathetic nerve. The result obtained from the conus arteriosus was similar to that of the intra-pulmonary artery. These results agree with YAGITA's histological study of the sensory nerves in the lung, and also with TAKINO's physiological results obtained under thoracotomy.

The results are summarized and illustrated in Fig. 8.

Sensory innervation of the peripheral arteries

The experiments performed in the femoral artery before and after the section of the peripheral spinal and the paravertebral lumbar sympathetic nerves demonstrated that the afferent fibers concerned in the reflex reaction ascended chiefly spinal and partially sympathetic pathways to reach the cord. This results supports the FOERSTER and KOYA's studies, in which sympathetic pathway has been emphasized as a pain conducting route of the peripheral artery. Concerning this problem, fuller account will be given later in the section of clinical experiments.

Sensory innervation of the abdominal visceral arteries

Experiments of the sensibility of visceral arteries before and after vagotomy and also spinal transection show the following result: the celiac artery and the superior mesenteric artery have dual sensory supply via the afferent pathways in the sympathetic and parasympathetic systems, whereas the inferior mesenteric artery has only one sensory supply via the sympathetic afferents and nothing to do with parasympathetic afferents.

Subsequently, the spinal segments which innervate these arteries were decided using KOYA's method. The following results were obtained: the celiac artery is

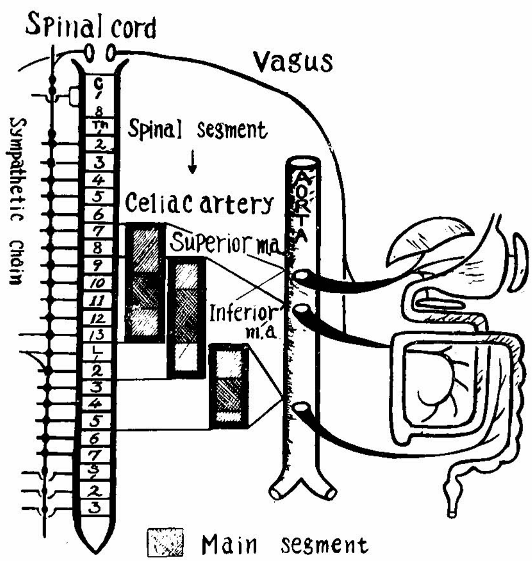

Fig. 9 Sensory nerve innervation of 3 main visceral arteries. Showing vagal afferent pathway and spinal segments innervating those arteries. Main segment: In each artery, the afferent fibers enter the spinal cord mainly at this segments.

innervated by Th7-Th13, the superior mesenteric artery by Th9-L2, and the inferior mesenteric artery by L1-L5. In comparison of the author's results with KOYA's which were obtained by stimulating those arteries on their adventitia, some difference is to be detected.

It is of interest that the spinal segments correspond to dermatoms of abdominal wall reflected from the same arteries that have been recently decided by the author's electromyographic studies of the viscero-moter reflexes. Furthermore, it is to be noted that the spinal segments innervating the above-mentioned three arteries agree with those of the viscera supplied with the vessels.

The results is illustrated in Fig. 9.

III CLINICAL EXPERIMENTS

VISCERAL ARTERIES

Almost the same stimulation method as employed in the animal experiments was carried out in the patients suffering from abdominal diseases during laparotomy.

In case 1, 2, and 3 of Table II, just before the resection of the stomach including ulcer or cancer, the electrodes were inserted into the right or left gastroepiploic artery as far as 10 cm and electric stimulation was given. None of the patients felt pain, even when they felt cardialgia by the electric stimulation of the gastric ulcer itself or the adventitial side of the gastroepiploic artery.

In case 4 with chronic appendicitis, we examined this catheter method in mesentric artery and confirmed the occurrence of cardialgia.

Table. II Result of Stimulation of Visceral Arteries

No. of Case, Name, Age & Sex	Diagnosis	Anesthesia	Stimulated artery	Stimuli applied to intima or adventitia	Pain	Site of feeling
(1) N. T. 51 M.	Gastric ulcer	Segmental spinal anesthesia	Right gastroepiploic artery	Square wave current 1ms, 60 cps, 1–40 V. to intima	−	
(2) O. B. 47 M.	Gastric ulcer	Segmental spinal anesthesia	Left gastroepiploic artery	〃 to intima	−	
(3) T. M. 72 M.	Gastric cancer	Local anesthesia	Right gastroepiploic artery	〃 to intima to adventitia	− +	Epigastrium
(4) M. S. 34 F.	Chronic appendicitis	Spinal Anesthesia	Ileocolic artery	〃 to intima	+	Epigastrium & right hypochondrium

PERIPHERAL ARTERIES AND VEINS

Six patients were examined for studying peripheral vascular sensibility.

Case 1 of Table III, a 40-year-old male, with sarcoma on the upper arm, was

Table. III Result of Stimulation of peripheral Blood Vessels

No. of Case. Name, Age & Sex	Diagnosis	Anesthesia	Stimulated vessel	Intesity of stimuli (volts)	Pain	Grade and character of pain
(1) T. F. 40. M.	Sarcoma of the upper arm	Local anesthesia	Profunda brachii artery	2	−	No pain
				10	±	Slight, only local
				20	+	Moderate } local, and spread to finger
				30	+	Severe } local, and spread to finger
				40	+	Severe } local, and spread to finger
(2) M. T. 55 M.	Varix of the leg	Local anesthesia	Large saphenous vein			
			Portion in the lower leg	0.5	−	No pain
				1	+	Slight, only local
				10	+	Moderate, local, and spread to 4cm distal
				20	+	Moderate, local, to 10cm
				30	+	Severe, } local, to 12cm
				40	+	Severe, } local, to 12cm
			Portion in the upper leg	1	−	No pain
				10	+	Slight, only local
				20	+	Moderate, local, to 10cm
				30	+	Severe, } local, to 15cm
				35	+	Severe, } local, to 15cm
(3) K. H. 50 M.	Thromboangiitis obliterans (left lower leg)	Spinal anesthesia (upper level Th 7)	Common iliac artery (left)	40	+	Severe pain, spread to the toes After periarterial sympathectomy, no pain
(4) M. S. 35 F.	Thromboangiitis obliterans	Local anesthsia	Popliteal artery	40	−	No pain
				Intra-arterial injection of $BaCl_2$	+	Severe pain, in region of the patella

examined before amputation. The stimulating electrodes were inserted into a branch of the brachial artery. Stimulation of 10 volts in electric potential gave him a pain only in the stimulated region, but with that of 20 volts the pain evidently spread to his fingers.

Case 2, a 55-year-old male, with varicose veins in the lower extremities, was examined during excision of varix. The large saphenous vein, at the lower leg portion, by the stimulation of 1 volt, produced a pain only in the stimulated point, but as the electric potential grew stronger, spreading of the pain began to appear. It, however, never extended more than 12 cm distal from the stimulated point, even when 40 volts potentials were given. Almost the same result was obtained at the upper leg portion of the vein. Besides, this result was confirmed in other two cases.

In case 3, a 50-year-old male, suffering from thromboangiitis obliterans, the electric stimulus was applied to adventitia of the left common illac artery after the left lumbar sympathetic ganglionectomy under the spinal anesthesia. Stimulation of 40 volts caused a severe pain which spread from the stimulated region to the toes.

After periarterial sympathectomy at the bifurcation of abdominal aorta, the pain disappeared.

In case 4, a 35-year-old female, suffering from thromboangiitis obliterans, the electric stimulus was applied to adventitia of the popliteal artery after complete local anesthesia of the vessel and the tibial nerve. The electric stimulation to adventitia caused no sensation of pain at all. Then intra-arterial injection of isotonic barium chloride solution (2.3%, 1cc) was performed at the same portion. After the injection, she felt a severe pain in the region of patella.

DISCUSSION

From these clinical experiments we know that: the intima of a blood vessel is less sensitive than the adventitia. The blood vessels in the extremities are more sensitive than those in the visceral regions. This fact agrees with the result of animal experiments. In the extremities, the arterial pain easily radiates to the fingers and toes, while the venous pain spreads only within a limited area. This suggests the existence of different modes of sensory innervation between large arteries and large veins.

The result of case 3 of Table III showed that some vascular sensory nerves of the lower extremities ascended along of the adventitia and entered the spinal cord at the level of at least above Th7 segment via the sympathetic ganglions and chains which belonged to segments more cranial than L 1. Because, even when the L 2, 3, and 4 sympathetic ganglionectomy had been performed under the spinal anesthesia below Th7, the stimulation of the iliac artery caused a severe pain spreading to the toes.

The experiment in case 4 of Table III, obviously proved that the pain caused by the injection of barium chloride solution arose from peripheral capillary and its surrounding tissues. Therefore, as already discussed, such chemical irritants were not suitable for the studies of vascular sensibility.

IV SUMMARY AND CONCLUSIONS

(1) A new method was devised by the author for the study of vascular sensibility in the strict sense of the word. The blood vessels were electrically stimulated by the coaxial electrodes which were set on the top of a heart catheter inserted into the blood vessels. As the indicator of the vascular sensibility, noci-reflexes, i. e., the changes of blood pressure and respiration were recorded on a kymogram.

(2) All blood vessels had sensibility and the intima of blood vessel was less sensitive than the adventitia.

The artery was always more sensitive than the vein in their anatomically corresponding portions.

The sensibility of the blood vessels in extremities showed a fact that the more peripheral the stimulated part is, the lower the threshold to stimulus is.

Comparing the vascular sensibility of the extremities with that of the main blood vessels in the trunk, the latter was less sensitive than the former.

(3) The vagal sensory fibers were classified into two kinds. One caused depressor reflexes from the aortic arch and the trunk of pulmonary artery, while the other produced noci-reflexes from the celiac and superior mesenteric artery, but not from the inferior mesenteric artery.

(4) From the metameric point of view, the viscera and the supplying blood vessels received the sensory nerves arising from the same segments of the spinal cord.

(5) The blood vessels of the lower extremities had a dual sensory supply via chiefly the spinal nerve and partially the sympathetic one.

(6) The arterial pain and venous pain showed some difference in spreading. From the clinical point of view, it may be possible that a vascular disease in a large artery causes a pain in the fingers and toes instead of the artery itself. But concerning the venous pain, such deception is not to be observed.

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和文抄録

血管知覚に関する生理学的研究

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(1) 血管知覚の生理学的研究に際しては実験方法の吟味，とくに戟刺方法の撰択に深い注意を払わねばならない．著者は従来から用いられている薬剤注入法は血管自身の知覚を検するためには不適当であることを知つたので，茲に新たに著者の創意に基づく血管内壁への電気刺戟法を用いて実験を行つた．即ち心臓カテーテルを使つて其の先端に同心電極を装着して，矩形波電流を以て血管内膜を刺戟した．血管知覚の表示としては侵害反射を指標とし，特に呼吸，血圧の変化を煤紙上に記録した．

(2) 血管知覚の存在が全血管に証明された 各部血管知覚の程度を測定して次の結果を得た．血管内膜は外膜に比し知覚感度は低い．動脈は同名の静脈より知覚鋭敏である．四肢血管と軀間血管との比較では前者がより鋭敏であり，同一四肢血管では末梢程鋭敏である．此の事は四肢端の如く交感神経緊張度の最も高い部分では知覚も亦鋭敏であり，それより心臓側に向うに従つて次第に鈍くなつてゆく事を示している．

(3) 実験成績の系統的考察によつて血管から起る反射は大別して調圧反射と侵害反射とに分類された．前者の反射受容装置は頸動脈洞，大動脈弓，肺動脈分岐部等特殊の部位に存在し，これに対して侵害反射の受容器は血管の凡ゆる部分に分布する．前者の求心神経は副交感神経と走行を共にするのが普通であり，これに対して後者は交感神経，脊髄神経と通常同行している．然しながら副交感神経知覚路の総てが調圧反射関係路であるのではなく，一方に於て亦，侵害反射上向路たり得る．即ち腹部内臓血管知覚の実験に於て迷走神経は侵害反射伝達路の一部を形成している事が証明された．

(4) 内臓血管の知覚支配を脊髄分節に就て研究した結果次の成績を得た．腹腔動脈はTh7～Th13により，上腸間膜動脈はTh9～L2により，下腸間膜動脈はL1～L5によつて夫々支配される．之等の脊髄分節は内臓の知覚支配分節と一致している．然し血管知覚神経は独立して血管壁に終末するものであつて，内臓の其れとは別箇のものである．それ故内臓知覚は血管知覚なりとの説は成立しない．此の両者は唯同一支配系統に属するのみである．

(5) 下肢血管は大部分脊髄神経性知覚伝導路，一部分交感神経性知覚伝導路によつて，2重知覚支配を受ける．

(6) 血管痛の放散様式について動静脈間に差違を認めた．即ち四肢の動脈の知覚は末梢へ放散性が強く，静脈の知覚は放散性が少ない．従つて四肢動脈痛は指趾痛として感ぜられ易いが同じ静脈の疼痛は刺戟部位に限局され部位感は比較的明瞭である．